



The Effect of GeoGebra-Assisted Problem-Based Learning on Junior High School Students' Mathematical Problem-Solving Skills

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ABSTRACT

Mathematical problem-solving ability is one of the essential competencies required for students in the 21st century. However, various educational evaluations indicate that Indonesian junior high school students still demonstrate relatively low problem-solving skills. One promising instructional approach to address this issue is the implementation of GeoGebra-assisted Problem-Based Learning (PBL). This study aimed to investigate the effect of GeoGebra-assisted Problem-Based Learning on junior high school students' mathematical problem-solving ability. A quantitative approach with a quasi-experimental design using a pretest-posttest control group design was employed. The sample consisted of 64 eighth-grade students divided into experimental and control groups. Data were collected through mathematical problem-solving tests and analyzed using descriptive statistics and independent sample t-tests. The findings revealed that students who participated in GeoGebra-assisted Problem-Based Learning demonstrated significantly higher improvements in mathematical problem-solving ability than those receiving conventional instruction. These results support previous studies highlighting the effectiveness of integrating GeoGebra into problem-based learning environments. Therefore, GeoGebra-assisted Problem-Based Learning can be recommended as an effective instructional alternative for enhancing junior high school students' mathematical problem-solving ability.

Article History

Received 2026-04-13

Revised 2026-04-15

Accepted 2026-06-23

Published 2026-06-27

Keywords

GeoGebra,
Mathematical problem
solving,
Problem-based
learning,
Secondary education

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Introduction

Mathematical problem-solving ability is one of the key competencies that students must possess in 21st-century mathematics education. This competency not only serves as an indicator of success in learning mathematics but also functions as a means for students to develop logical, critical, systematic, and creative thinking skills in addressing various real-life problems. Mathematical problem-solving enables students to apply mathematical concepts, principles, and procedures to find solutions to both routine and non-routine situations. Therefore, the development of problem-solving skills has become an important objective in various modern mathematics curricula. However, classroom realities indicate that students' mathematical problem-solving abilities remain a significant challenge that requires serious attention from educators and curriculum developers.

The low level of students' mathematical problem-solving ability is often reflected in their difficulties in understanding information presented in problems, determining appropriate solution strategies, carrying out solution procedures systematically, and evaluating the results obtained. This condition suggests that mathematics instruction still tends to focus on procedural mastery and formula memorization rather than the development of higher-order thinking skills. Consequently, students may be able to solve routine problems that follow patterns similar to examples provided by teachers, but they struggle when confronted with problems requiring analysis, interpretation, and deeper conceptual application. This situation

highlights the need for instructional innovations that provide more meaningful learning experiences and place students at the center of the learning process.

One instructional model considered relevant for improving mathematical problem-solving ability is Problem-Based Learning (PBL). This model positions problems as the starting point of learning, encouraging students to engage in exploration, investigation, discussion, and reflection to find solutions to the given problems. Through this process, students not only acquire conceptual knowledge but also develop critical thinking skills, collaborative abilities, and decision-making skills based on available information. Research conducted by Parindang and Abdurrahman (2025) demonstrated that the implementation of the Problem-Based Learning model positively influences students' mathematical problem-solving abilities. The findings revealed that students' active involvement in the problem-solving process enhances both conceptual understanding and the quality of solution strategies employed.

The effectiveness of Problem-Based Learning in improving mathematical problem-solving ability is also supported by various other studies. Sahela and Frisnoiry (2023) found that the implementation of Problem-Based Learning in teaching solid geometry significantly improved the problem-solving abilities of eighth-grade students. Similar findings were reported by Putra et al. (2025), who demonstrated that problem-based learning positively contributes to students' ability to understand, analyze, and solve mathematical problems. These findings reinforce the view that Problem-Based Learning is an appropriate instructional approach for developing problem-solving competencies because it provides students with opportunities to learn through direct experiences in solving authentic problems.

Nevertheless, the successful implementation of Problem-Based Learning is greatly influenced by the availability of instructional media and learning resources that support students' exploratory activities. In mathematics learning, many concepts are abstract and often difficult to understand through verbal explanations or conventional media alone. This condition may hinder students from constructing accurate conceptual representations. Therefore, the utilization of educational technology is needed to help students visualize mathematical concepts more concretely and interactively. One software application widely used in mathematics education is GeoGebra.

GeoGebra is a dynamic mathematics software that integrates geometry, algebra, statistics, graphing, and calculus within an interactive learning environment. The use of GeoGebra allows students to visually explore mathematical concepts through the direct manipulation of mathematical objects. According to Ramadhani and Narpila (2018), GeoGebra can enhance the quality of mathematics learning by helping students understand the relationships between visual and symbolic representations of mathematical concepts. The visualization capabilities provided by GeoGebra make learning more engaging and enable students to conduct independent mathematical investigations. Thus, GeoGebra functions not only as a teaching aid for instructors but also as a learning tool that encourages active student participation.

The use of GeoGebra in mathematics instruction has demonstrated various positive impacts on students' learning outcomes. Carli (2023) reported that GeoGebra-assisted learning significantly improved both student learning activities and academic achievement. The exploratory activities facilitated through GeoGebra provide students with opportunities to identify patterns, test hypotheses, and verify obtained solutions. Such processes support the development of stronger conceptual understanding compared to instruction that relies solely on one-way information delivery. Therefore, integrating GeoGebra into mathematics instruction represents a promising alternative for enhancing both the learning process and learning outcomes.

In recent years, researchers have increasingly focused on integrating GeoGebra with the Problem-Based Learning model. The integration of these two components is considered capable of creating a more effective learning environment by combining problem-solving activities with dynamic mathematical visualization. Through this approach, students are not only required to find solutions to given problems but also receive visual support that clarifies relationships among mathematical concepts. Amalia et al. (2023) found that GeoGebra-assisted Problem-Based Learning significantly improved students' mathematical problem-solving abilities. Their findings indicated that students who learned through GeoGebra-assisted PBL

demonstrated superior abilities in understanding problems, planning solution strategies, and evaluating the solutions obtained.

Similar findings were reported by Samosir and Salayan (2023), who showed that problem-based learning supported by GeoGebra positively influenced students' mathematical problem-solving abilities. In their study, students who participated in GeoGebra-assisted instruction exhibited greater improvement than those who received conventional instruction. Suratno and Waliyanti (2023) also found that integrating GeoGebra into Problem-Based Learning enhanced students' problem-solving skills by helping them understand complex mathematical concepts through more accessible visual representations. These findings indicate that GeoGebra can strengthen the effectiveness of Problem-Based Learning in achieving mathematics learning objectives.

In addition to influencing problem-solving ability, the integration of GeoGebra into Problem-Based Learning also positively affects other mathematical competencies. Research by Amallya et al. (2024) showed that GeoGebra-assisted Problem-Based Learning improved both mathematical communication skills and problem-solving abilities. Strong mathematical communication skills enable students to express ideas, explain solution strategies, and interpret results more systematically. Consequently, GeoGebra not only helps students understand mathematical concepts but also supports mathematical communication and argumentation throughout the learning process.

Research conducted by Nilasari et al. (2024) demonstrated that GeoGebra-assisted Problem-Based Learning positively affected both students' mathematical problem-solving abilities and their interest in learning mathematics. These findings suggest that the use of technology in education influences not only cognitive aspects but also students' affective dimensions. When students are interested and motivated to participate in learning activities, they tend to become more actively engaged in the problem-solving process. Such active engagement ultimately contributes to improved learning outcomes.

The effectiveness of GeoGebra-assisted Problem-Based Learning has also been demonstrated across various mathematics topics. Anggraeni et al. (2023) found that Problem-Based Learning supported by interactive PowerPoint integrated with GeoGebra improved students' mathematical problem-solving abilities. Aulya et al. (2024) reported similar results in the topic of circle equations, while Silalahi and Panjaitan (2022) demonstrated improvements in students' problem-solving abilities in solid geometry. These findings indicate that the effectiveness of GeoGebra-assisted PBL is not limited to a specific mathematical topic but can be applied to various subjects requiring visualization and deep conceptual understanding.

Recent studies have also shown further developments in the implementation of GeoGebra-assisted PBL through integration with other instructional approaches. Pradiarti et al. (2025) found that GeoGebra-assisted PBL combined with the Teaching at the Right Level (TaRL) approach improved students' problem-solving abilities in linear function topics. Meanwhile, Soliha and Amidi (2025) reported that differentiated instruction integrated with GeoGebra-assisted PBL positively affected students' mathematical problem-solving abilities. These findings demonstrate GeoGebra's high flexibility for integration with various student-centered instructional approaches that address learners' needs and characteristics.

Stronger empirical evidence regarding the effectiveness of GeoGebra-assisted PBL was provided through a meta-analysis conducted by Anzani and Juandi (2022). The meta-analysis revealed that the use of GeoGebra in problem-based learning produced a positive effect size on students' mathematical abilities. This finding provides a strong theoretical and empirical foundation for the conclusion that the combination of Problem-Based Learning and GeoGebra is an effective instructional strategy for improving various mathematical competencies, including problem-solving ability.

Although numerous studies have reported positive findings, previous research still exhibits variations in research contexts, learning materials, student characteristics, and instructional implementations. Some studies focus on improving learning activities, learning interest, or mathematical communication skills, while research specifically examining the influence of GeoGebra-assisted Problem-Based Learning on junior high school students' mathematical problem-solving ability still requires stronger empirical evidence. Furthermore,

differences in school characteristics, student conditions, and learning environments may lead to variations in research outcomes, highlighting the need for further investigation to strengthen the consistency of existing findings.

Based on the foregoing discussion, this study aims to analyze the effect of GeoGebra-assisted Problem-Based Learning on junior high school students' mathematical problem-solving abilities. This research is expected to contribute theoretically by strengthening empirical evidence regarding the effectiveness of integrating Problem-Based Learning and GeoGebra in mathematics education. In addition, it is expected to provide practical contributions for teachers and schools in developing more innovative, interactive, and student-centered instructional strategies aimed at improving students' mathematical problem-solving abilities.

Method

Research Design

This study employed a quantitative approach using a quasi-experimental research method. The selection of this method was based on the objective of the study, namely to examine the effect of the GeoGebra-assisted Problem-Based Learning (PBL) model on junior high school students' mathematical problem-solving abilities. The research design used was a pretest-posttest control group design, which allowed the researcher to compare changes in mathematical problem-solving abilities between the group receiving the treatment and the group receiving conventional instruction.

In this design, both groups were administered a pretest to determine students' initial abilities before the treatment was implemented. Subsequently, the experimental group participated in learning activities using the GeoGebra-assisted Problem-Based Learning model, while the control group received conventional instruction commonly practiced by the teacher. After the completion of the instructional intervention, both groups were given a posttest to measure their mathematical problem-solving abilities after the treatment. The differences in outcomes between the two groups served as the basis for determining the effect of implementing GeoGebra-assisted PBL on students' mathematical problem-solving abilities.

Research Site and Participants

The study was conducted during the second semester of the 2024/2025 academic year at a public junior high school in Indonesia. The population consisted of all eighth-grade students distributed across four parallel classes with relatively homogeneous academic characteristics based on the school's mathematics achievement records.

The sample was selected using the cluster random sampling technique. This technique was chosen because the sampling units were intact classroom groups that had already been formed. Through a random selection process, two classes were chosen as research samples. One class was assigned as the experimental group and received instruction through the GeoGebra-assisted Problem-Based Learning model, while the other class was assigned as the control group and received conventional instruction. The total sample consisted of 64 students, including 32 students in the experimental group and 32 students in the control group.

Sample selection also considered the equivalence of initial abilities among classes. Therefore, prior to the treatment, all students completed a pretest to ensure that there were no significant differences in initial mathematical problem-solving abilities between the experimental and control groups.

Research Instruments

The primary instrument used in this study was a mathematical problem-solving ability test. The instrument was developed based on four indicators of problem-solving ability: (1) understanding the problem, (2) planning a solution strategy, (3) implementing the solution strategy, and (4) reviewing the solution obtained. These indicators were used to assess students' abilities to solve mathematical problems systematically.

The test was administered in the form of essay questions, allowing students to demonstrate their reasoning processes and solution procedures comprehensively. Prior to its use in the study, the instrument underwent a validation process conducted by mathematics

education experts and mathematics teachers to ensure the appropriateness of its content, construct, and language. Subsequently, the instrument was piloted with students possessing characteristics similar to those of the research sample to determine its validity and reliability. The results of the pilot testing indicated that the instrument was appropriate for measuring students' mathematical problem-solving abilities.

In addition to the mathematical problem-solving test, the study also utilized learning materials consisting of instructional modules, student worksheets, and GeoGebra-based teaching materials tailored to the mathematics topics taught during the research period.

Research Procedure

The study was conducted through several stages. The first stage was the preparation phase, which included developing research instruments, designing instructional materials, validating instruments, and determining the research sample. During this phase, the researcher also coordinated with school administrators and mathematics teachers regarding the research schedule.

The second stage involved administering the pretest to both the experimental and control groups. The pretest was conducted to obtain information about students' initial abilities before participating in the instructional intervention. The pretest results were then analyzed to ensure the equivalence of the two groups.

The third stage was the treatment phase. In the experimental group, learning activities were implemented using the GeoGebra-assisted Problem-Based Learning model. The instructional process began with the presentation of contextual problems related to the learning materials. Students then worked collaboratively in groups to identify problems, formulate solution strategies, conduct explorations using GeoGebra, and discuss their findings. The teacher acted as a facilitator, guiding students throughout the investigation and discussion processes.

Meanwhile, the control group received conventional instruction characterized by teacher-centered explanations, worked examples, and practice exercises. GeoGebra was not utilized during the instructional process in this group.

The final stage was the administration of the posttest to measure students' mathematical problem-solving abilities after the treatment had been completed. The posttest results were subsequently used to evaluate the effectiveness of the GeoGebra-assisted Problem-Based Learning model compared with conventional instruction.

Data Analysis Techniques

The research data were analyzed using both descriptive and inferential statistics. Descriptive statistical analysis was employed to describe the characteristics of the data, including mean scores, maximum scores, minimum scores, and standard deviations of the pretest and posttest results for both groups.

Before hypothesis testing was conducted, prerequisite tests consisting of normality and homogeneity tests were performed. The normality test was used to determine whether the data were normally distributed, while the homogeneity test was conducted to examine the equality of variances between the experimental and control groups. The results of these prerequisite tests served as the basis for selecting the appropriate statistical analysis techniques.

Hypothesis testing was conducted using an independent samples t-test at a significance level of 0.05 to determine whether there was a significant difference in mathematical problem-solving abilities between the experimental and control groups after the treatment. In addition, students' learning improvement was analyzed using the normalized gain (N-Gain) score to determine the effectiveness level of the instructional intervention. The results of these analyses were used to draw conclusions regarding the effect of the GeoGebra-assisted Problem-Based Learning model on junior high school students' mathematical problem-solving abilities.

Results and Discussion

Research Results

This study aimed to analyze the effect of the GeoGebra-assisted Problem-Based Learning (PBL) model on junior high school students' mathematical problem-solving abilities. Measurements were conducted through the administration of a pretest before the treatment and a posttest after the treatment in both the experimental and control groups. The research data are presented in Table 1.

Table 1. Descriptive Statistics of Pretest, Posttest, and N-Gain Scores of Mathematical Problem-Solving Ability

Group	Number of Students	Mean Pretest Score	Mean Posttest Score	N-Gain
Experimental Group (PBL assisted by GeoGebra)	32	54.13	84.38	0.66
Control Group (Conventional Learning)	32	53.47	72.19	0.40

Table 1 shows that the initial abilities of both groups were relatively similar. This is evident from the mean pretest score of the experimental group, which was 54.13, and the control group, which was 53.47. The small difference indicates that both groups had nearly equivalent initial abilities before the treatment was implemented.

After the learning process, an improvement in mathematical problem-solving ability was observed in both groups. However, the improvement in the experimental group was higher than that of the control group. The mean posttest score of the experimental group reached 84.38, while the control group achieved 72.19. These findings indicate that learning using the PBL model assisted by GeoGebra produced better learning outcomes compared to conventional learning.

The improvement in students' abilities is also reflected in the N-Gain values. The experimental group obtained an N-Gain of 0.66, while the control group obtained 0.40. These results show that the improvement in mathematical problem-solving ability in the experimental group is in a better category compared to the control group.

Learning Achievement Comparison Diagram

Based on the data in Table 1, the research results can be presented as follows.

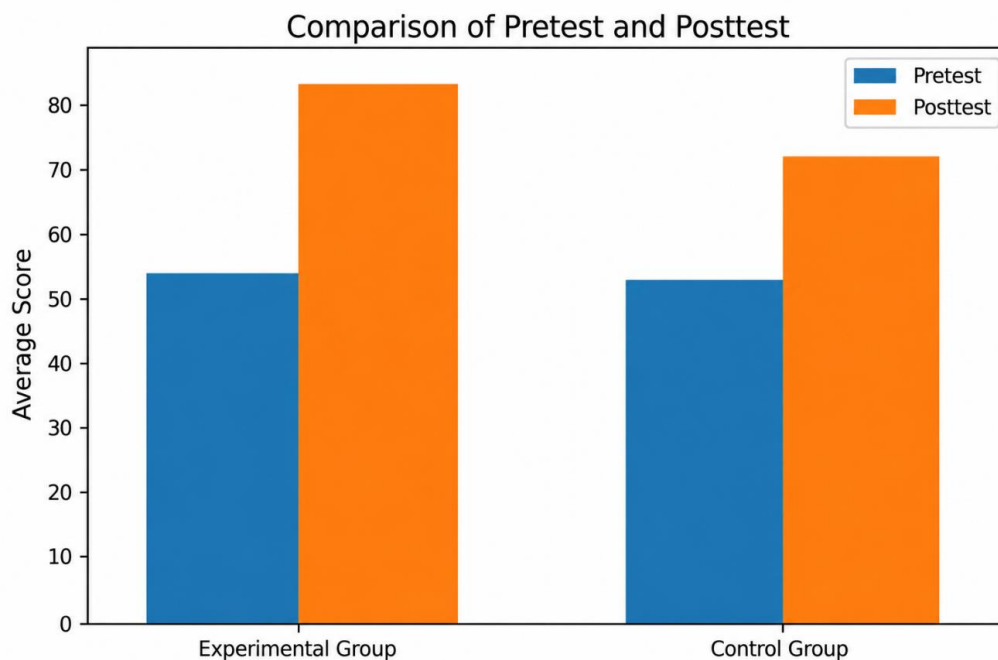


Figure 1. Comparison Of Pretest and Scores

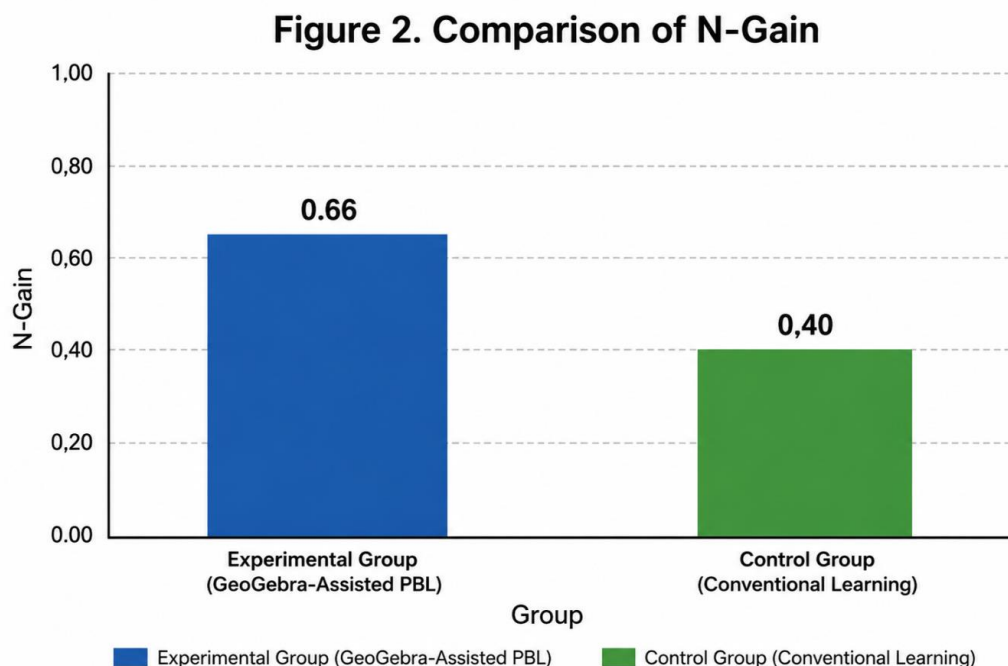


Figure2. ComparisonofN-Gain

Discussion

The results of the study indicate that the Problem-Based Learning model assisted by GeoGebra has a positive effect on students' mathematical problem-solving abilities at the junior high school level. This finding is evidenced by the higher increase in the average learning outcomes of the experimental group compared to the control group. These results suggest that the integration of problem-based learning with mathematical visualization technology can create a more effective learning experience in developing problem-solving skills.

The improvement in students' mathematical problem-solving abilities in the experimental group can be explained by the characteristics of the Problem-Based Learning model. In this model, students are actively involved in identifying problems, analyzing available information, formulating solution strategies, and evaluating the obtained solutions. These activities encourage students to construct knowledge independently through investigation and discussion processes. Students' active engagement in each learning stage provides broader opportunities to develop higher-order thinking skills required in mathematical problem solving. These findings are consistent with those of Parindang and Abdurrahman (2025) as well as Sahela and Frisnoiry (2023), who reported that the implementation of Problem-Based Learning can significantly improve students' mathematical problem-solving abilities.

In addition to the learning model, the improvement in students' abilities is also supported by the use of GeoGebra as a learning medium. GeoGebra provides visualization facilities that allow students to observe relationships between mathematical objects more concretely and dynamically. When students face mathematical problems, they can explore, simulate, and verify solutions using the visual representations available in GeoGebra. This helps students understand abstract concepts that are often obstacles in the problem-solving process. This finding supports the study of Ramadhani and Narpila (2018), which stated that GeoGebra can enhance conceptual understanding of mathematics through a visual and interactive approach.

The results of this study also strengthen the findings of Amalia et al. (2023), Samosir and Salayan (2023), and Suratno and Waliyanti (2023), who reported that the integration of GeoGebra in problem-based learning contributes positively to improving students'

mathematical problem-solving abilities. In GeoGebra-assisted learning, students do not only obtain final answers but also understand the process of deriving solutions through exploration of various mathematical representations. Thus, learning becomes more meaningful because students are given the opportunity to construct their understanding based on their own learning experiences.

These findings are also consistent with studies by Anggraeni et al. (2023), Aulya et al. (2024), Nilasari et al. (2024), Silalahi and Panjaitan (2022), Putra et al. (2025), Pradiarti et al. (2025), and Soliha and Amidi (2025), which show that the use of GeoGebra in problem-based learning can improve various mathematical abilities, particularly problem-solving skills. The consistency of these results indicates that GeoGebra is an effective medium to support the implementation of Problem-Based Learning across various mathematics topics. This finding is also in line with the meta-analysis by Anzani and Juandi (2022), which concluded that problem-based learning assisted by GeoGebra has a positive effect on students' mathematical abilities.

Theoretically, these findings strengthen the constructivist view, which emphasizes that knowledge is actively constructed through interaction between students and the learning environment. The Problem-Based Learning model provides a learning context that encourages students to discover and construct knowledge through problem solving, while GeoGebra functions as a tool that facilitates this knowledge construction process through dynamic mathematical visualization. The combination of both creates a learning environment that optimally supports the development of mathematical problem-solving abilities. Therefore, the implementation of Problem-Based Learning assisted by GeoGebra can be considered an effective alternative in mathematics instruction to improve the quality of both learning processes and outcomes at the junior high school level.

Conclusion

This study aimed to analyze the effect of the Problem-Based Learning (PBL) model assisted by GeoGebra on junior high school students' mathematical problem-solving abilities. Based on the research results, it can be concluded that the implementation of PBL assisted by GeoGebra has a positive effect on improving students' mathematical problem-solving abilities. This is indicated by the higher posttest mean scores and N-Gain values of the experimental group compared to the control group. These findings suggest that the integration of problem-based learning with GeoGebra can create a more effective learning process in helping students understand concepts, develop solution strategies, and evaluate obtained solutions.

The improvement in mathematical problem-solving abilities in the experimental group shows that the use of contextual problems in the PBL model encourages students to think actively, critically, and systematically in solving mathematical problems. On the other hand, GeoGebra serves as a visualization medium that helps students understand abstract mathematical concepts through more concrete and interactive representations. The combination of these two components provides a more meaningful, student-centered learning experience that supports the optimal achievement of mathematics learning objectives.

Theoretically, this study strengthens previous research findings stating that the integration of learning technology in problem-based learning models can improve students' mathematical abilities, especially problem-solving skills. Practically, the results of this study have implications for mathematics teachers to utilize GeoGebra as a supporting medium in the implementation of Problem-Based Learning to create more innovative, interactive, and higher-order thinking skill-oriented learning.

This study still has limitations in terms of sample size and research context, which is limited to one educational level and one school environment. Therefore, future research is recommended to involve larger samples, more diverse school contexts, and to examine the effectiveness of GeoGebra-assisted Problem-Based Learning on other mathematical abilities, such as critical thinking, mathematical communication, mathematical creativity, and mathematical literacy. In this way, the contribution of GeoGebra in mathematics learning can be understood more comprehensively and in greater depth.

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